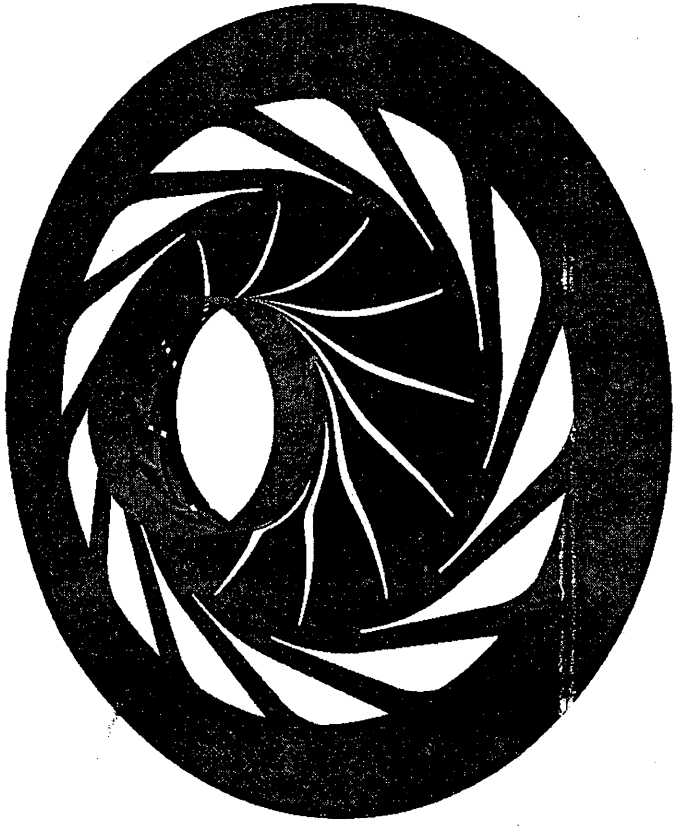
Steady and Unsteady Simulations of the Flow in an Impeller/Diffuser Stage



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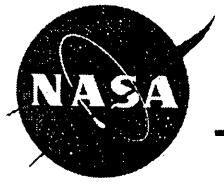
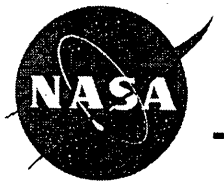


Overview

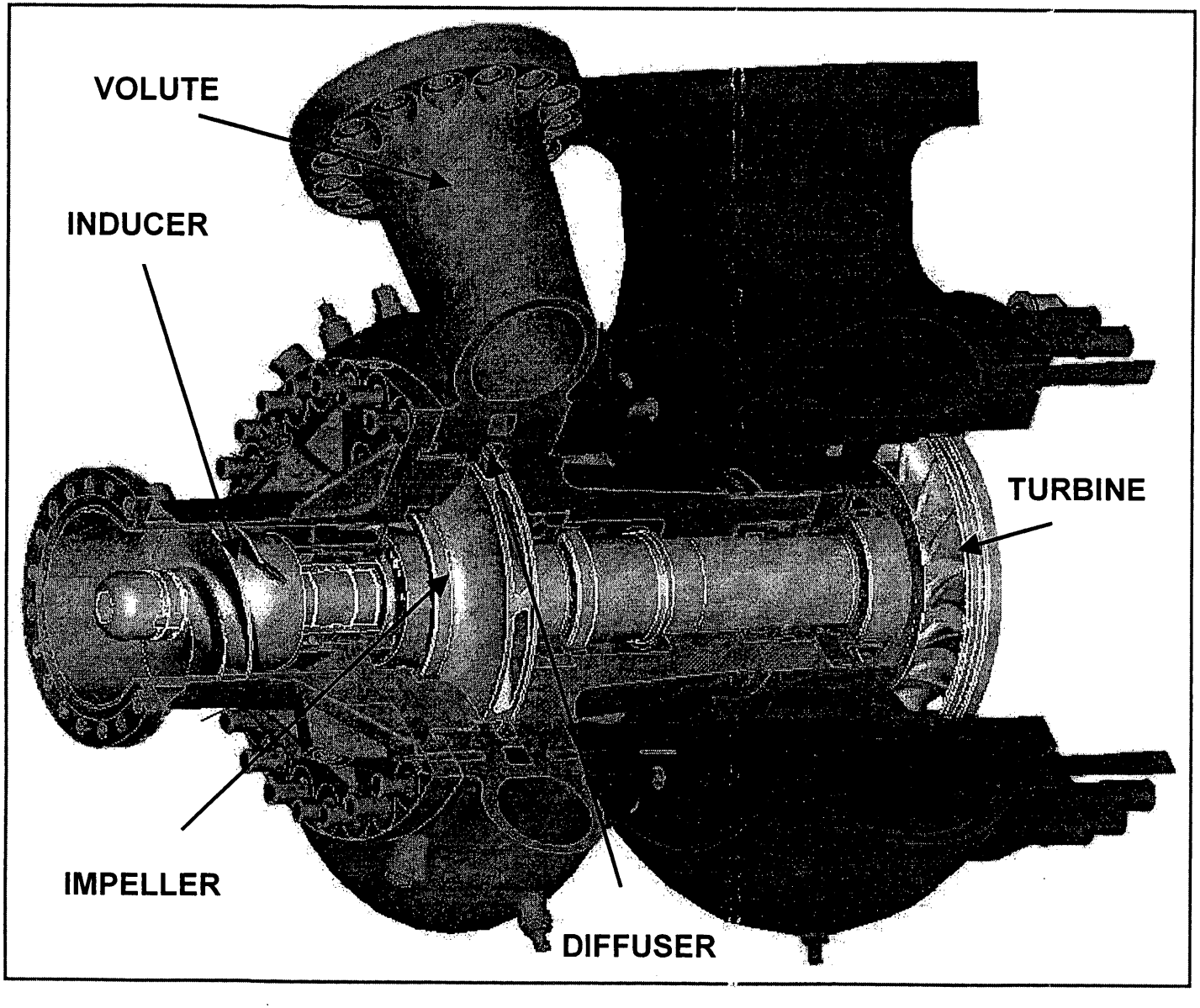
- **Problem definition**
- **CFD for design**
- **Impeller/diffuser test case**
  - TASCflow
  - Corsair
- **Conclusions and future plans**



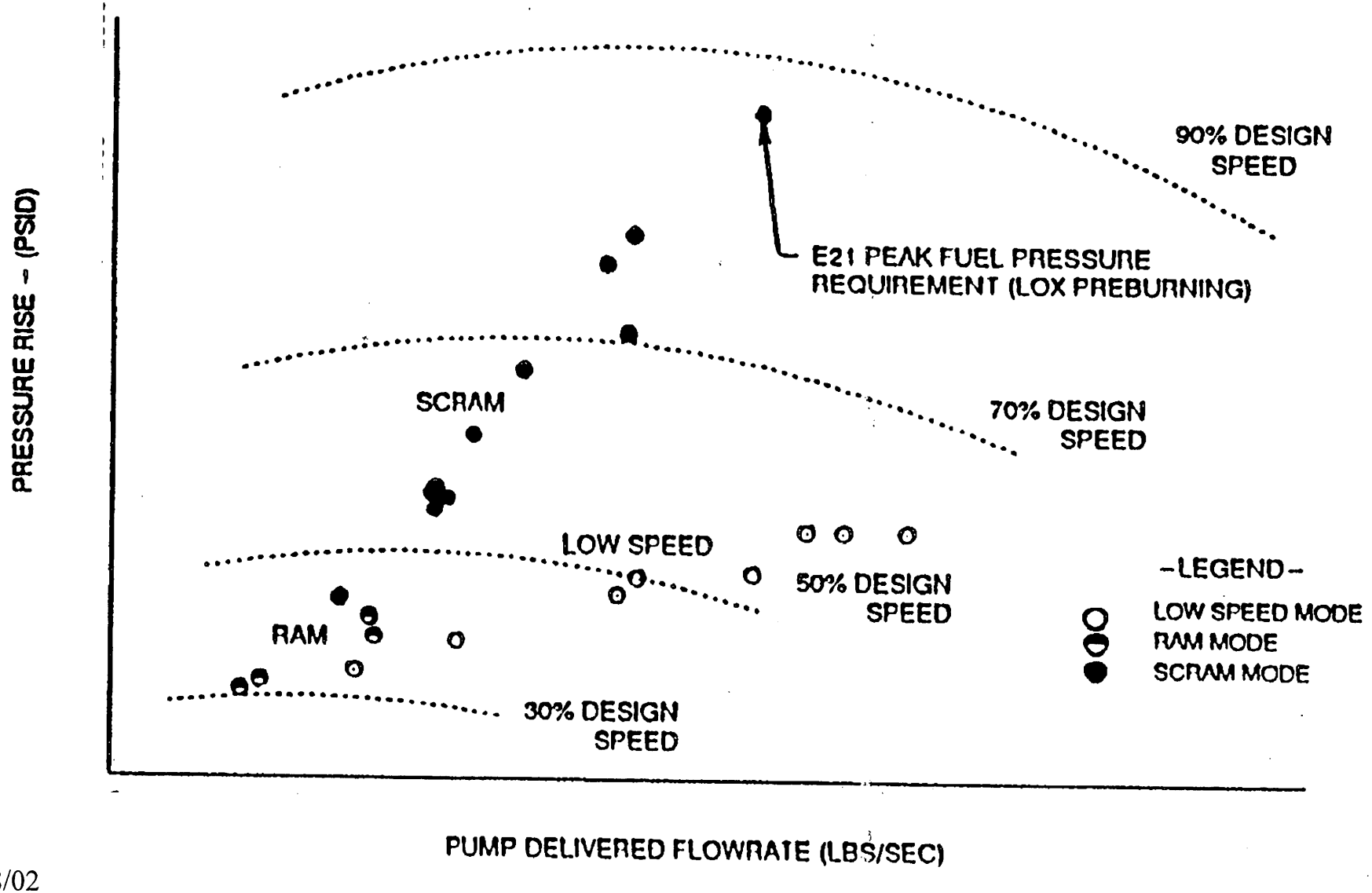
Problem Definition

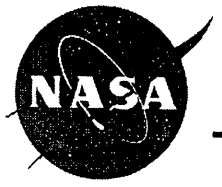
- **SLI engine designs will require pumps to throttle over a wide flow range while maintaining high performance**
- **Unsteadiness generated by impeller/diffuser interaction is one of the major factors affecting off-design performance**

Generic Oxidizer Turbopump



Deep Throttling of Turbopumps





CFD for Design

- **Unsteady flow simulations necessary for predicting impeller/diffuser interaction**
  - Steady simulations miss important off-design physics
- **Grid density based on a compromise between computational efficiency and solution accuracy**
  - design parametrics require many simulations in a short time frame
  - Simulations must resolve pertinent flow physics and unsteady frequencies (separation, stall cells, vortex shedding, etc.)

Pump Stage Test Case

HIGH-HEAD IMPELLER AND VANE ISLAND DIFFUSERS

IMPELLER BLADES (FULL)	6
IMPELLER BLADES (PARTIAL)	6
DIFFUSER VANES	13
FLUID	WATER
FLOW RATE	1210 GAL/MIN
ROTATION RATE	6322 RPM
FLOW COEFF.	0.144
TIP SPEED	249 FT/SEC
INLET SWIRL	63 DEG

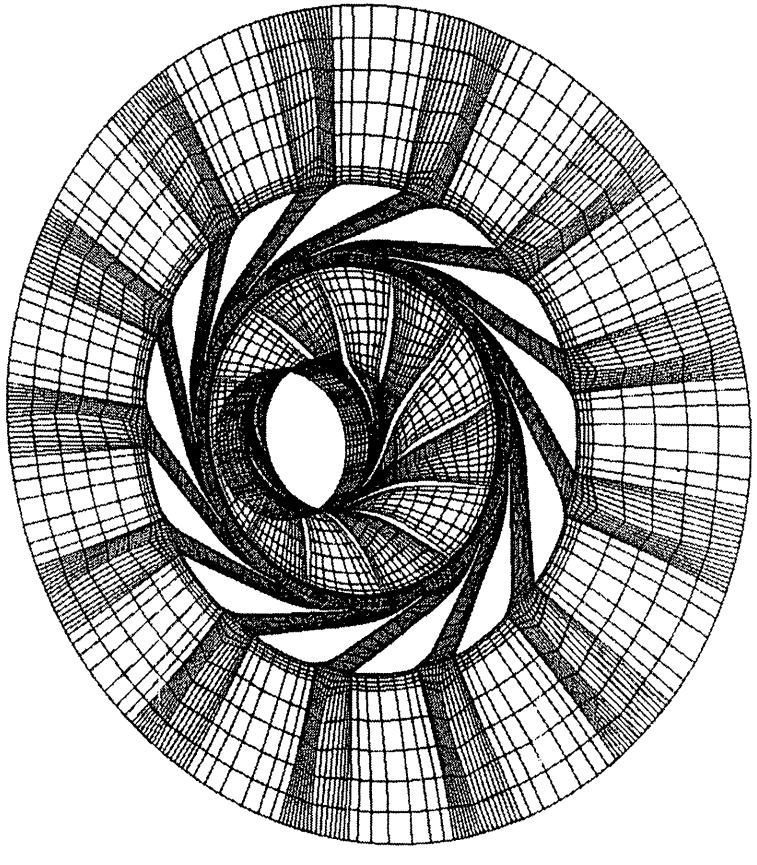
CFX/TASCflow

- Pressure-Based Coupled Solver
- Conservative Finite Element-Based Control Volume Method
- Advection Modeling Uses Skew Upstream Differencing Schemes with Physical Advection Correction
- Steady/Transient Analysis
- Compressible/Incompressible
- Stage/Frozen Rotor/Transient Rotor-Stator Interaction
- Moving Grid
- Parallel Implementation with PVM

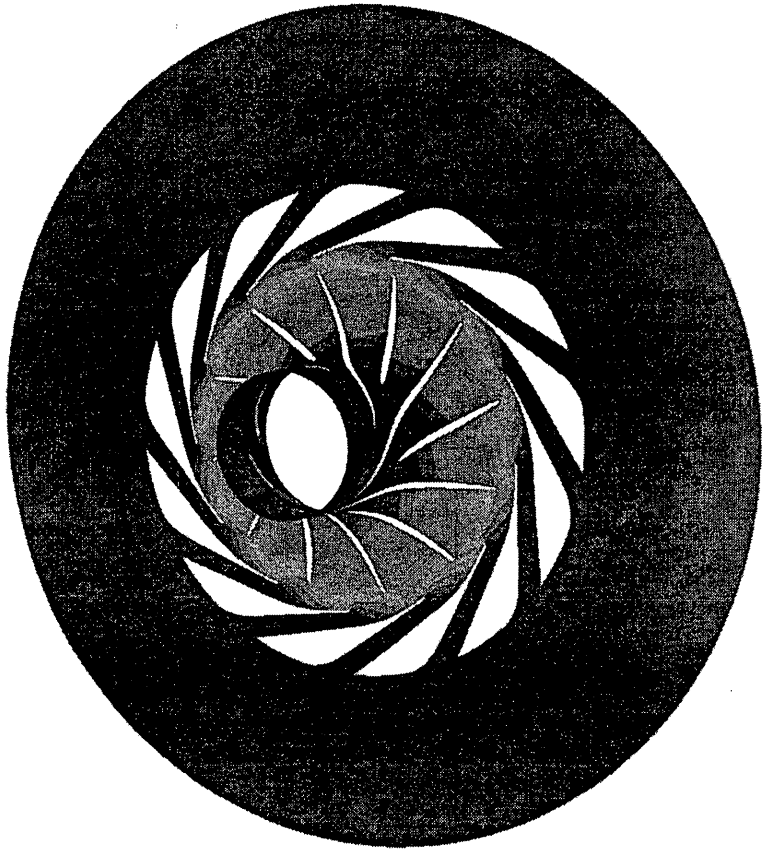
CFX/TASCflow Simulation

6 FULL + 6 SPLITTER IMPELLER BLADES AND 13 DIFFUSER VANES - 100% DESIGN FLOW - 300,000 GRID POINTS

RUN TIME: 1,152 cpu hours/revolution – 6 R12000 300 MHz processors

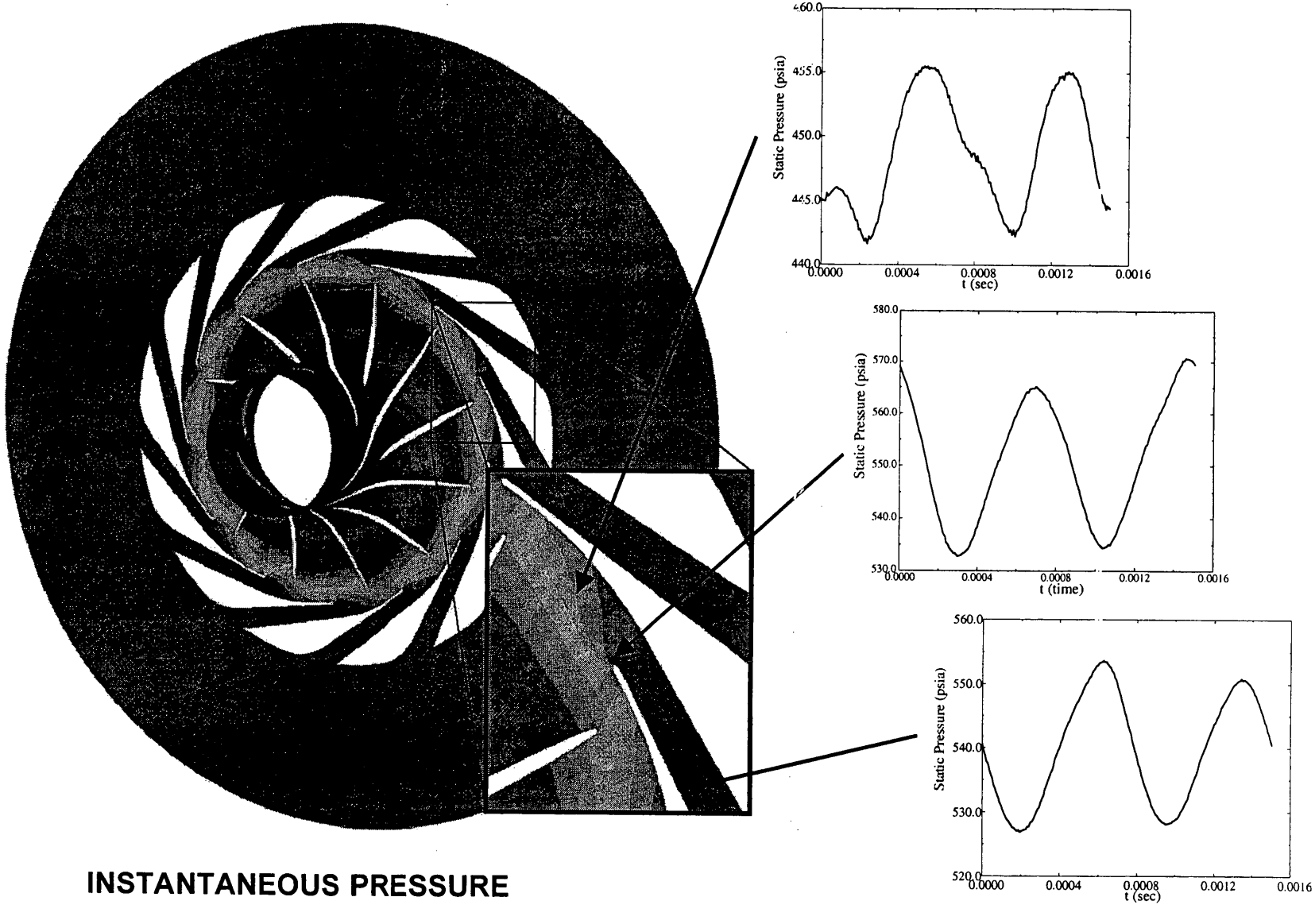


COMPUTATIONAL GRID



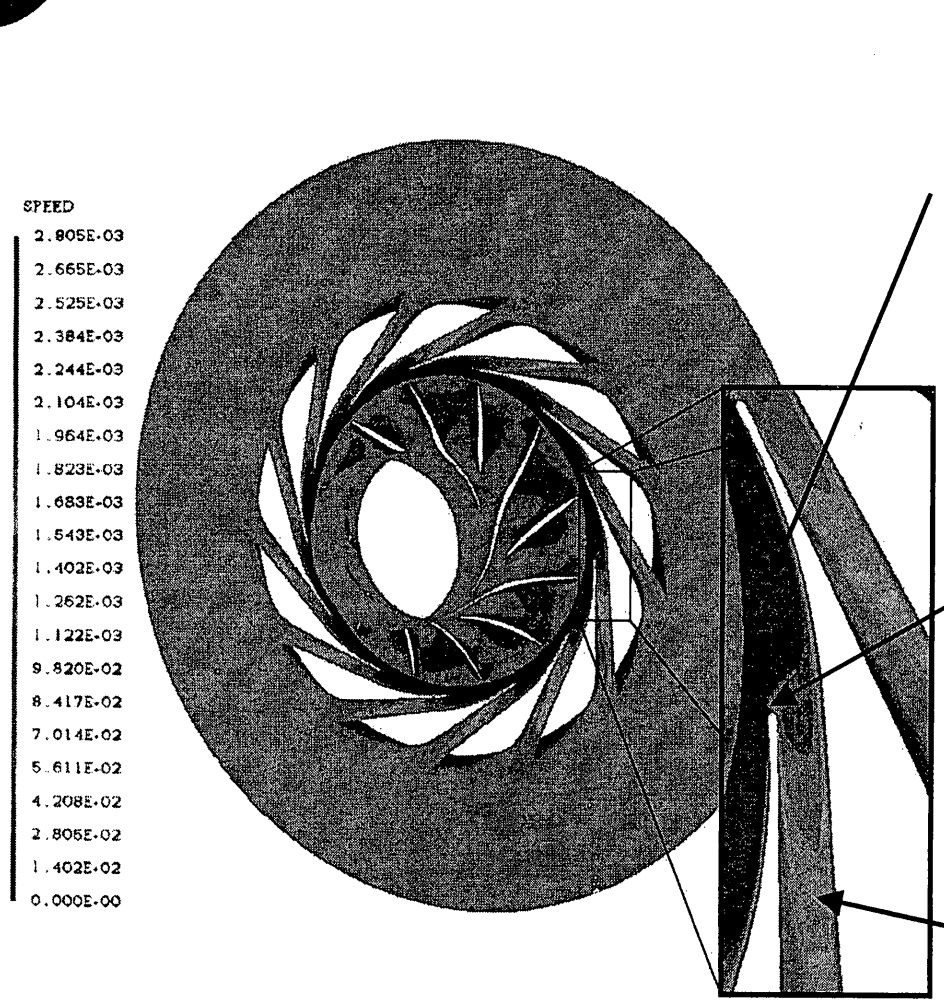
INSTANTANEOUS PRESSURE

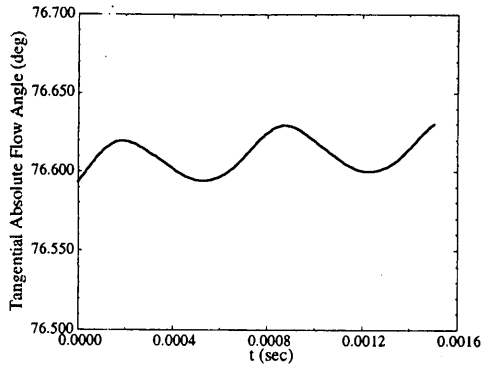
Unsteady Pressure

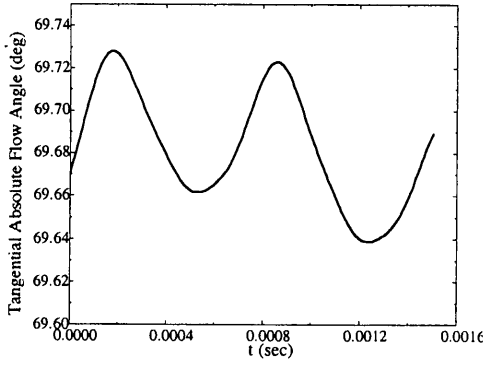


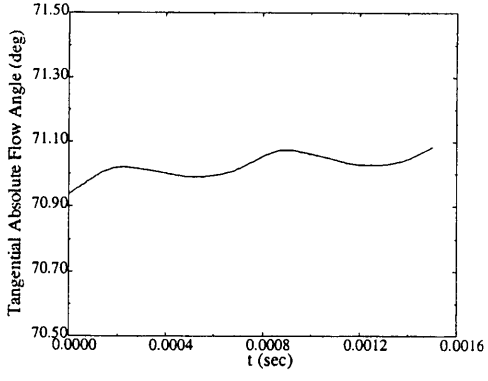
INSTANTANEOUS PRESSURE

Unsteady Flow Angle



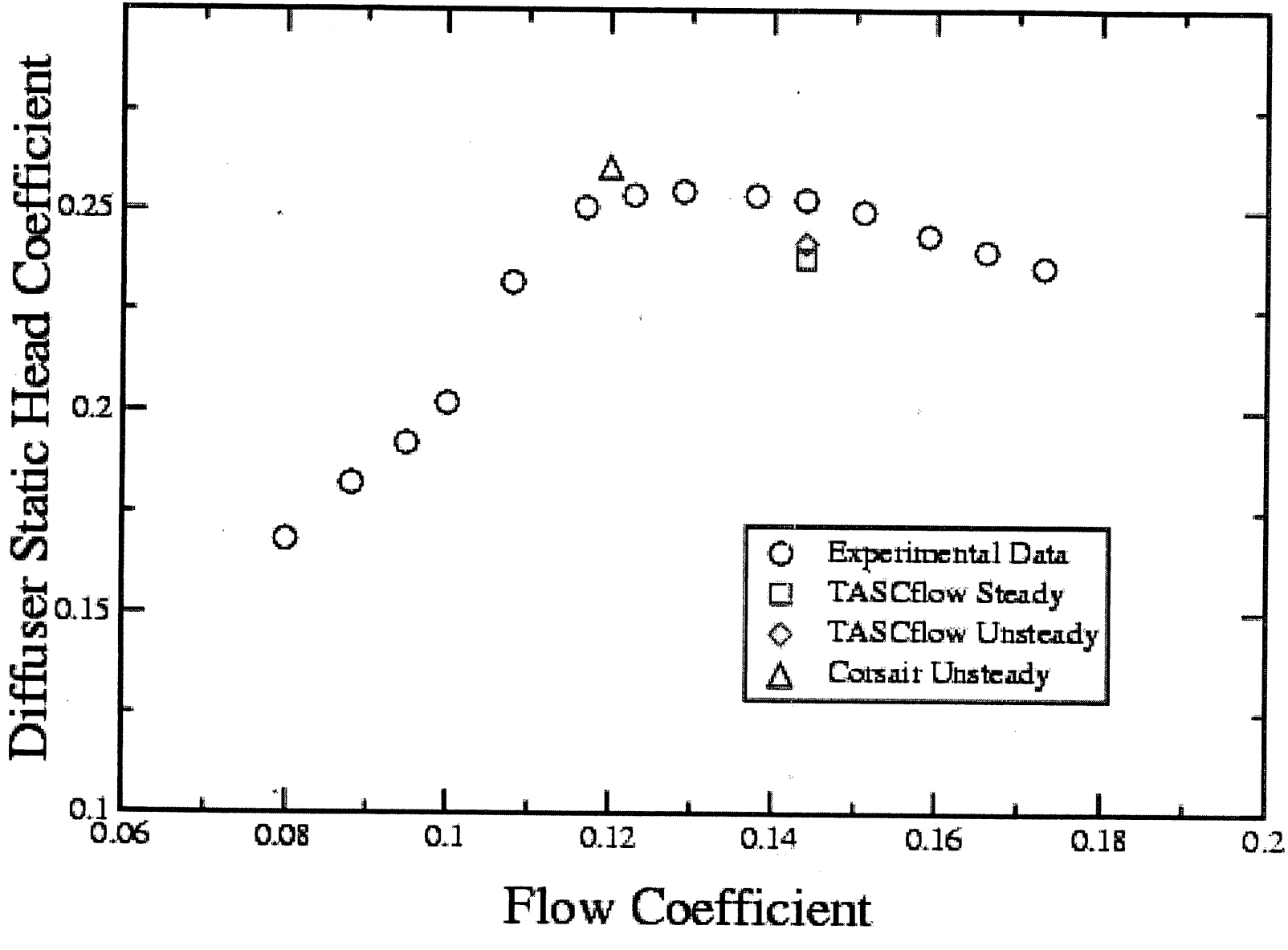


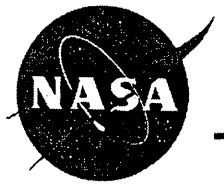




INSTANTANEOUS VELOCITY MAGNITUDE

Time-Avg Diffuser Static Head Coefficient





CORSAIR

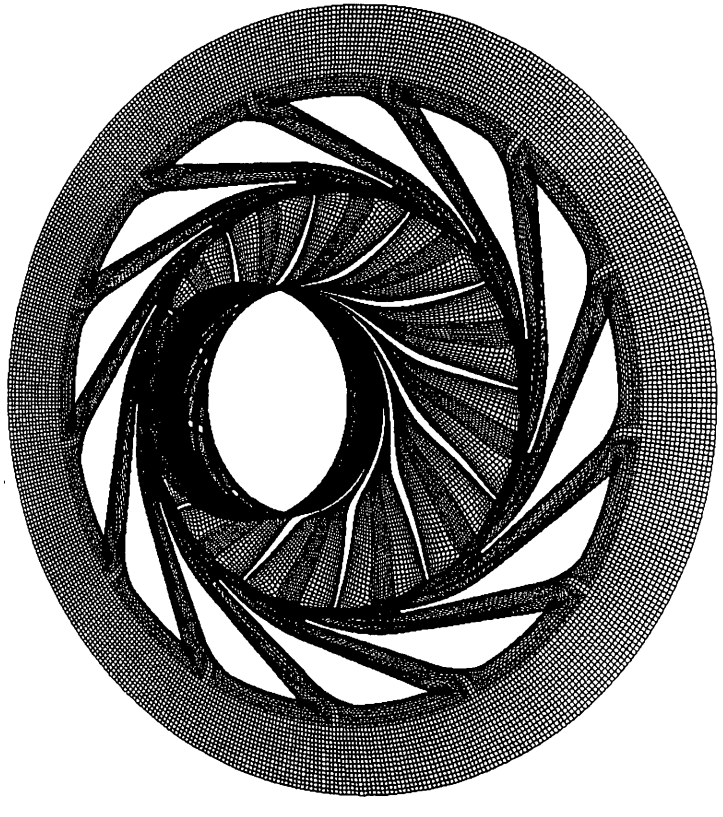
- Time-dependent equations of motion
- Implicit solution scheme
- Third-order spatial discretization of inviscid fluxes
- Second-order spatial discretization of viscous fluxes
- Second-order temporal accuracy
- Multi-block O-H grid topology
- Grid movement simulations blade motion
- MPI and OpenMp

Corsair Simulation

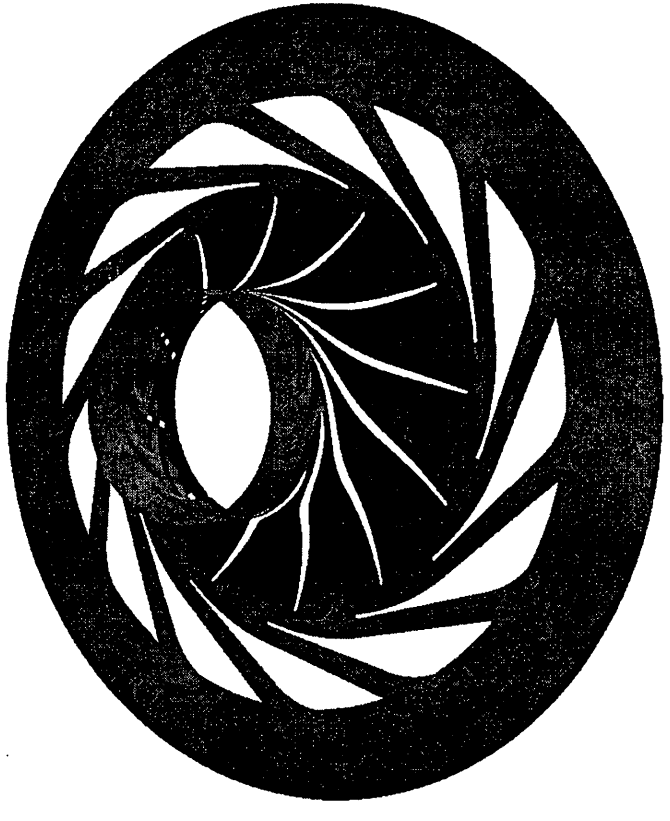
12 FULL IMPELLER BLADES AND 13 DIFFUSER VANES

83% DESIGN FLOW - 4.5 MILLION GRID POINTS

RUN TIME: 250 cpu hours/revolution – 32 R12000 400 MHz processors

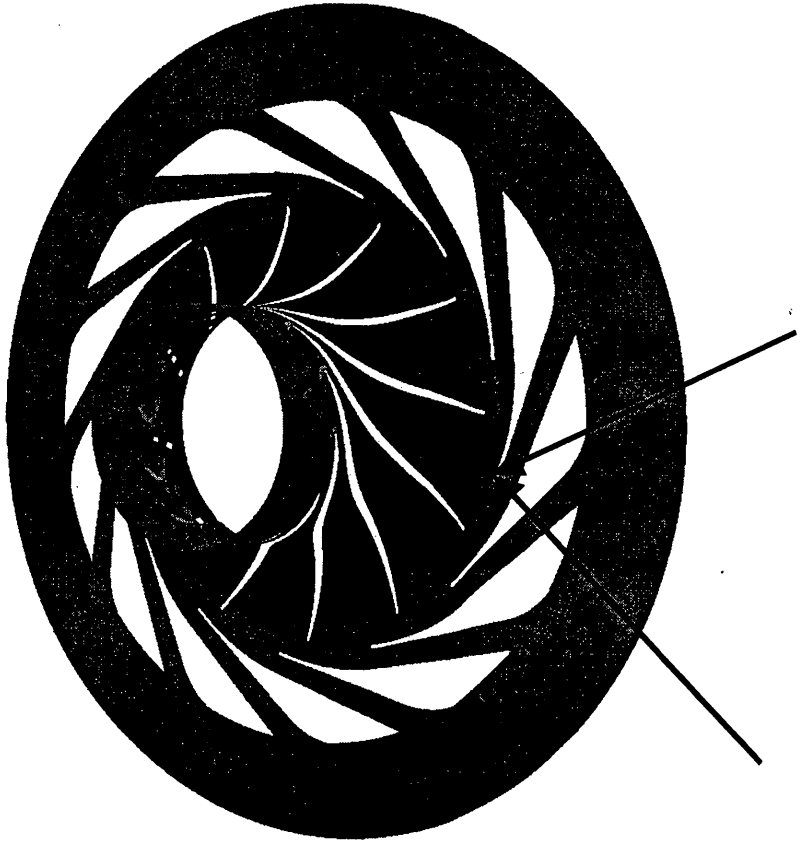


COMPUTATIONAL GRID

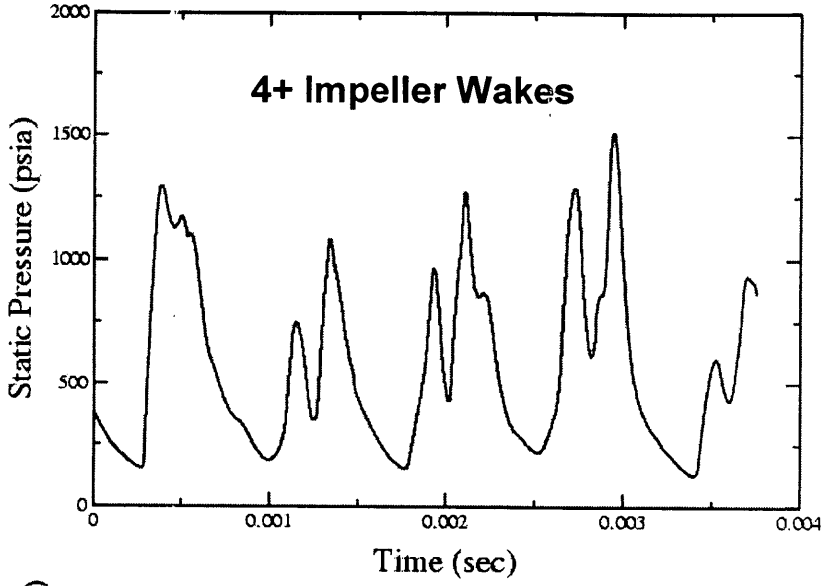


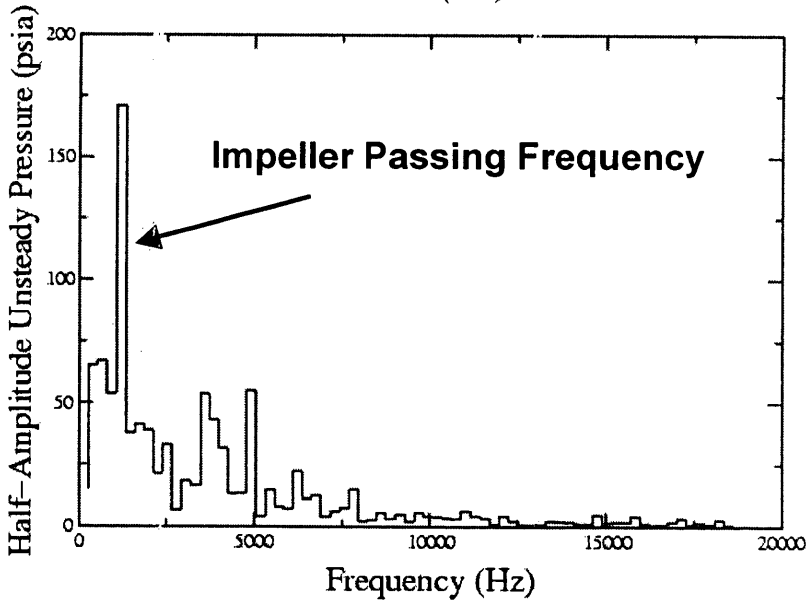
INSTANTANEOUS PRESSURE

Unsteady Pressure

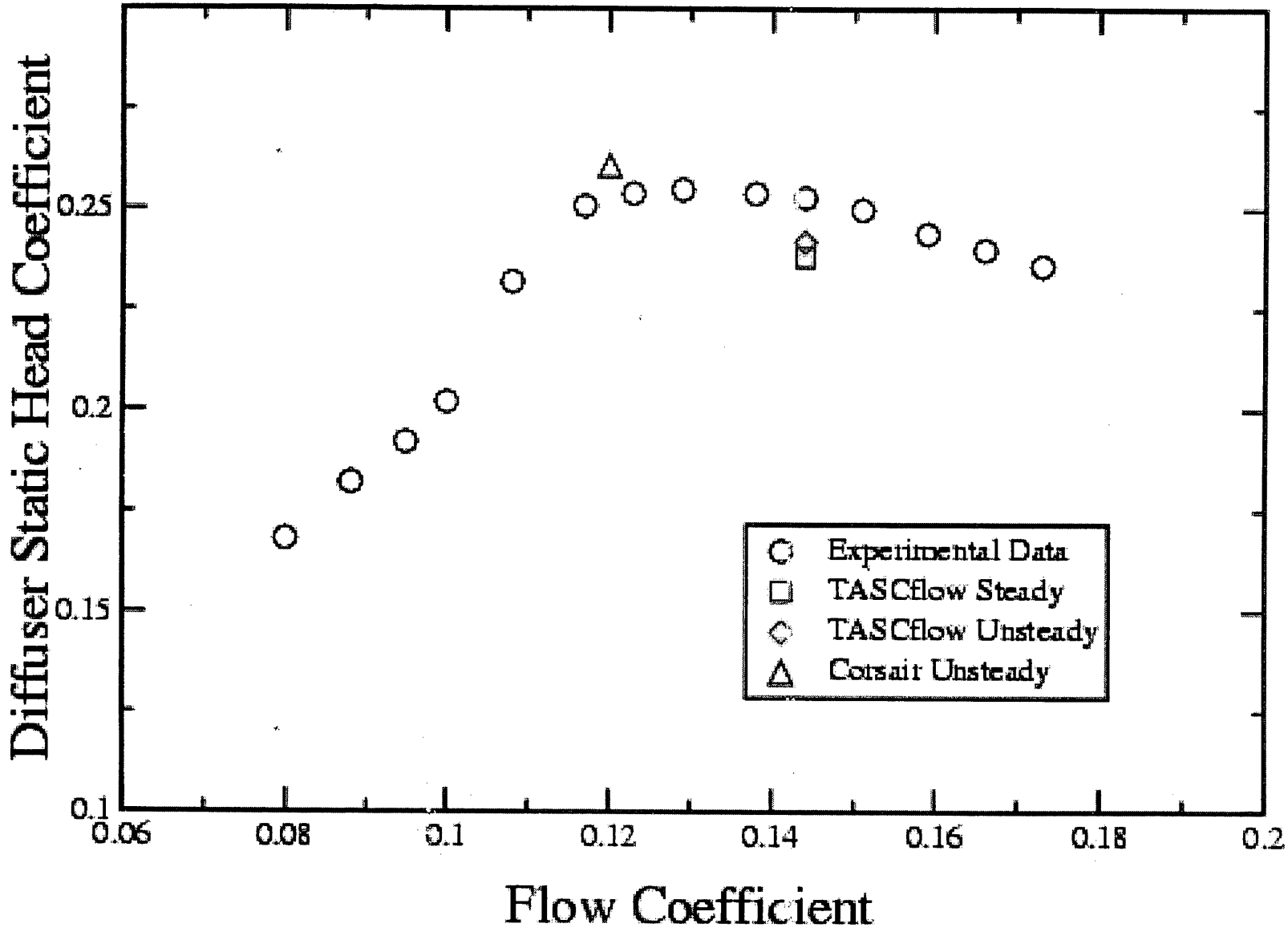


INSTANTANEOUS PRESSURE



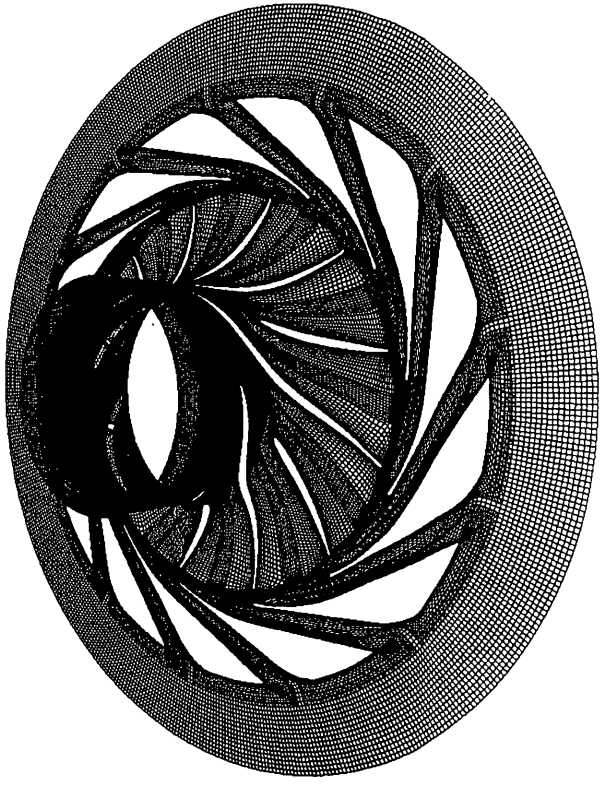


Time-Avg Diffuser Static Head Coefficient

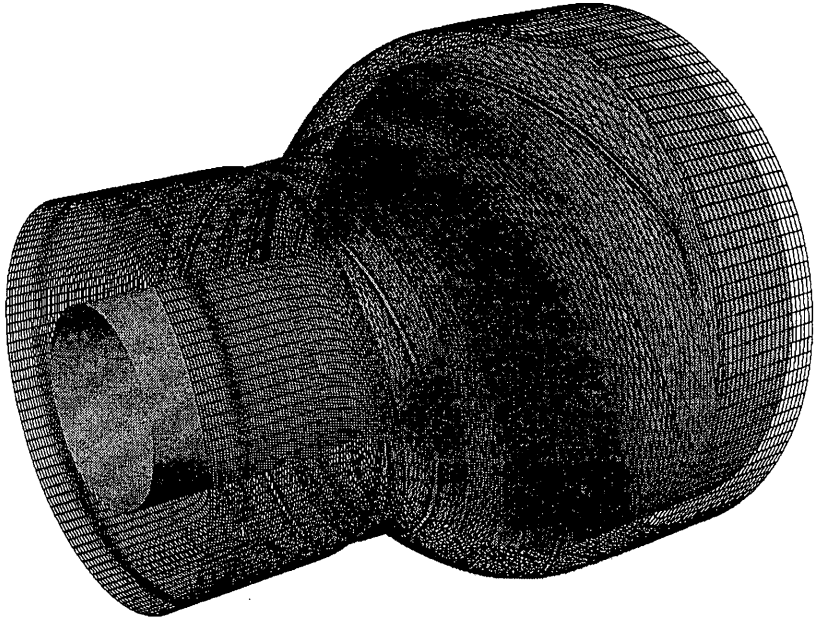


Pumps and Inducers

Full-Annulus Simulations in Progress



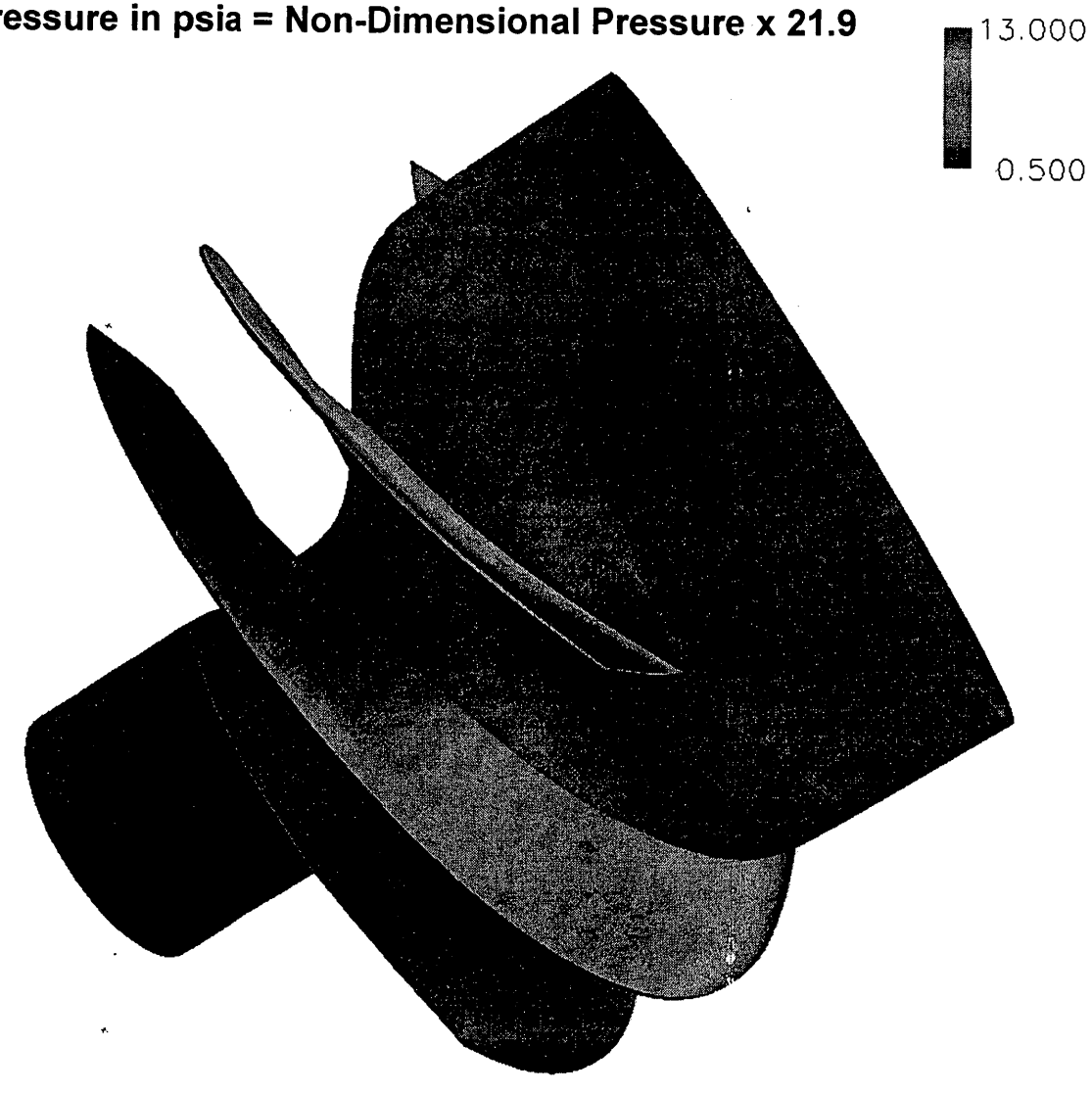
IMPELLER W/SPLITTERS

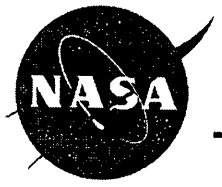


INDUCER

Inducer Instantaneous Pressure Field

Dimensional Pressure in psia = Non-Dimensional Pressure x 21.9





Conclusions and Future Plans

- Initial unsteady simulations completed for impeller/diffuser stage
- Corsair simulations to continue across wide flow range and for inducer/impeller/diffuser combination
- Results of unsteady simulations being used to guide/explore new designs